Deep Convective Clouds and Chemistry

May – June 2011 Colorado - Alabama

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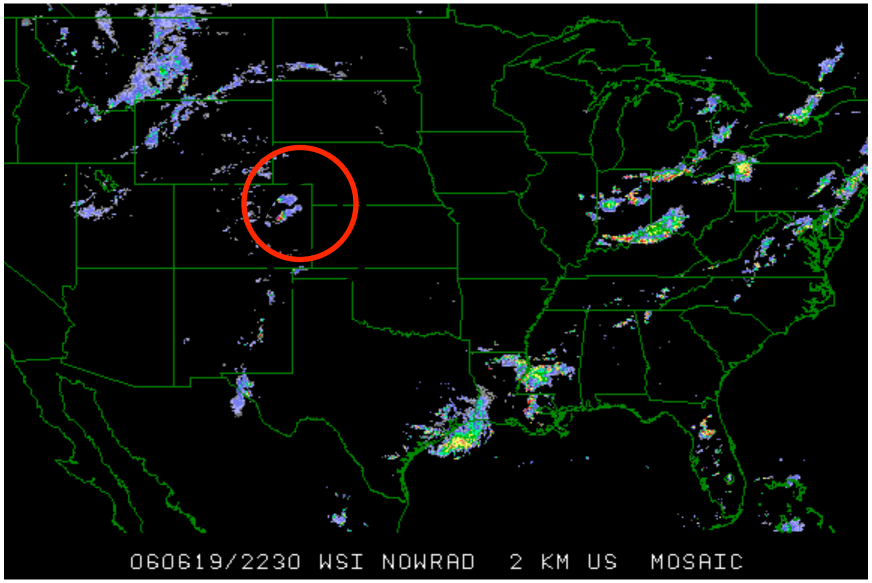
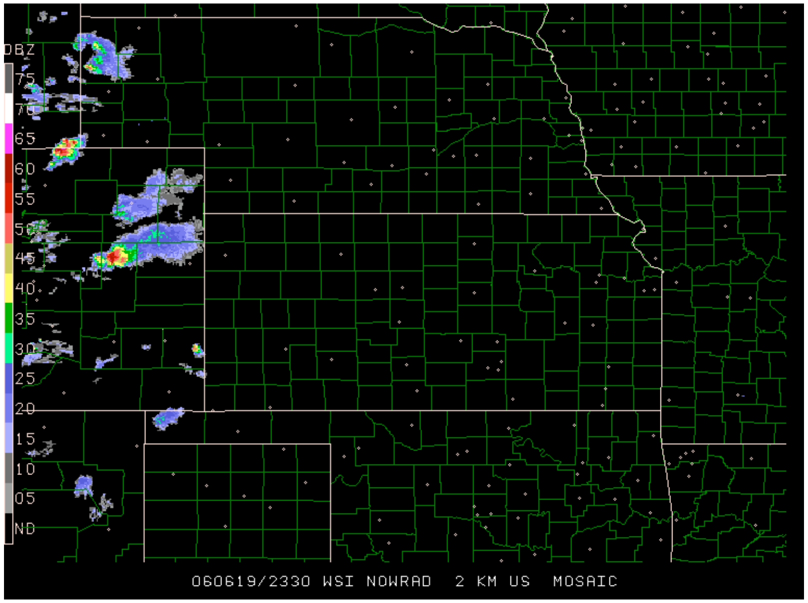
- ASP is charged with improving understanding and representation of the aerosol life cycle.
- Deep convection plays important roles in vertical transport, aqueous-phase production, nucleation, and scavenging of trace chemicals and particulate matter.
- The representation of this influence in global climate models is highly uncertain.
- DOE does not have an aircraft that can sample detrainment of trace species from deep convection.
- The DC3 experiment proposed to NSF would provide upper tropospheric measurements that would complement DOE measurements in the lower troposphere.

DC3 Goals

1. *To quantify and characterize the convection and convective transport within the first few hours of active convection, investigating:*

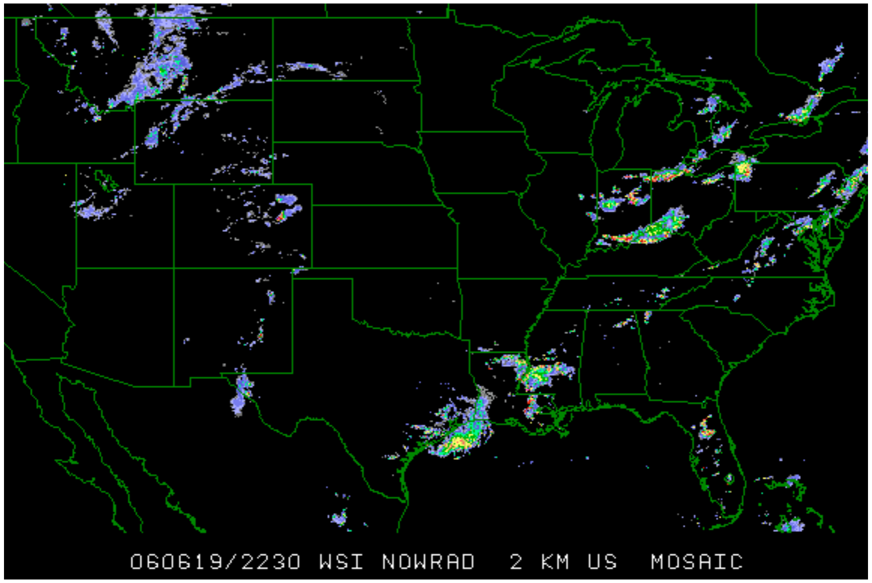
- *storm dynamics and physics,*
- *lightning and its production of nitrogen oxides,*
- *cloud hydrometeor effects on wet scavenging of species,*
- *chemistry in the anvil*

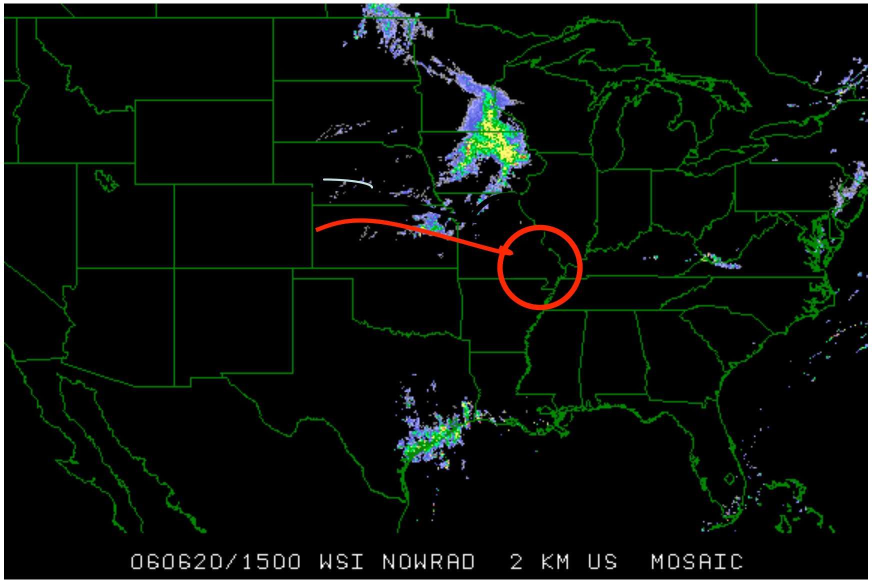




DC3 Goals

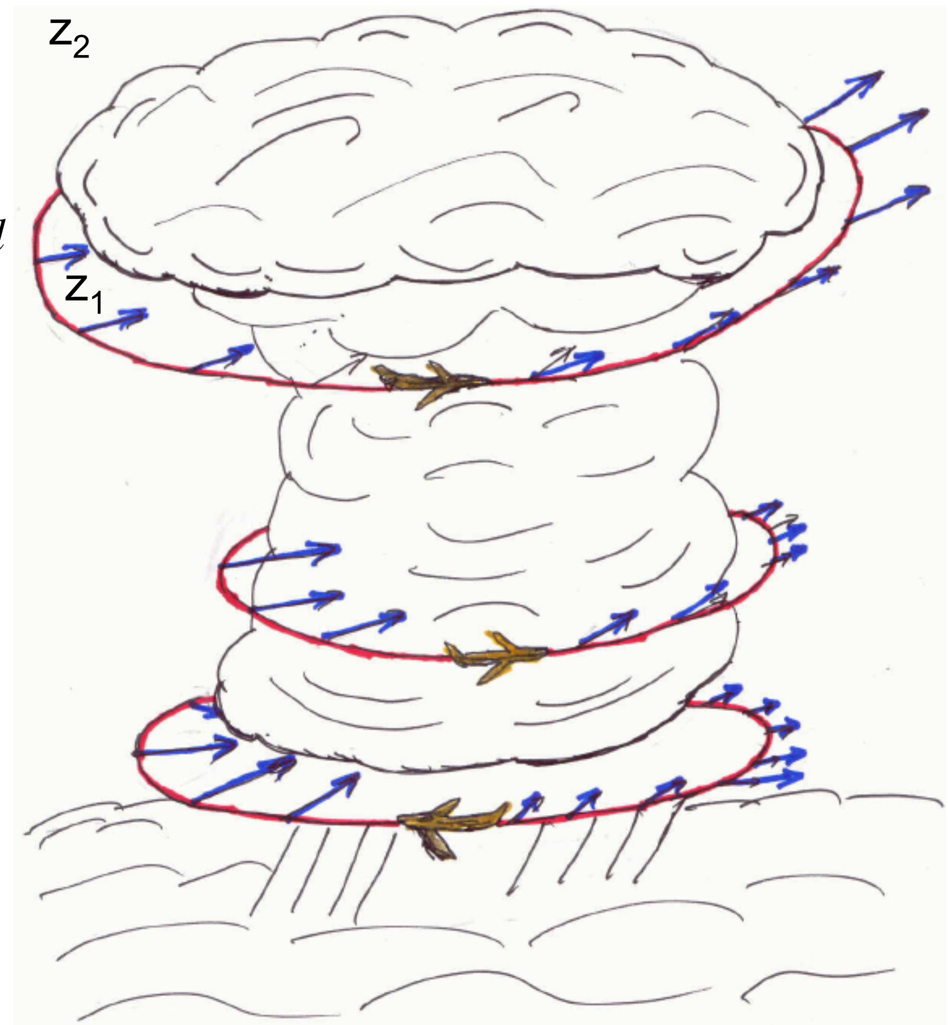
2. *To quantify the changes in chemistry and composition after active convection, focusing on*
- *12-48 hours after convection and*
- *the seasonal transition of the chemical composition of the upper troposphere*





A Sampling Strategy (Don Lenschow)

- Circles around cloud cloud at 3 km altitude intervals
- Flux of q into cloud: $F_q(z) = \frac{1}{A}\oint_C v_\perp q\,dl$
- Entrainment below z_1: $E_q = \int_0^{z_1} \rho F_q dz$
- Detrainment above z_1: $D_q(z) = \int_{z_1}^{z_2} \rho F_q dz'$
- Scavenging ratio $S_q = \frac{E_q - D_q}{E_q}$
    - S=0 for dry air
    - S~1 for soluble gases and large soluble particles
    - S<<1 for insoluble gases



Key Platforms

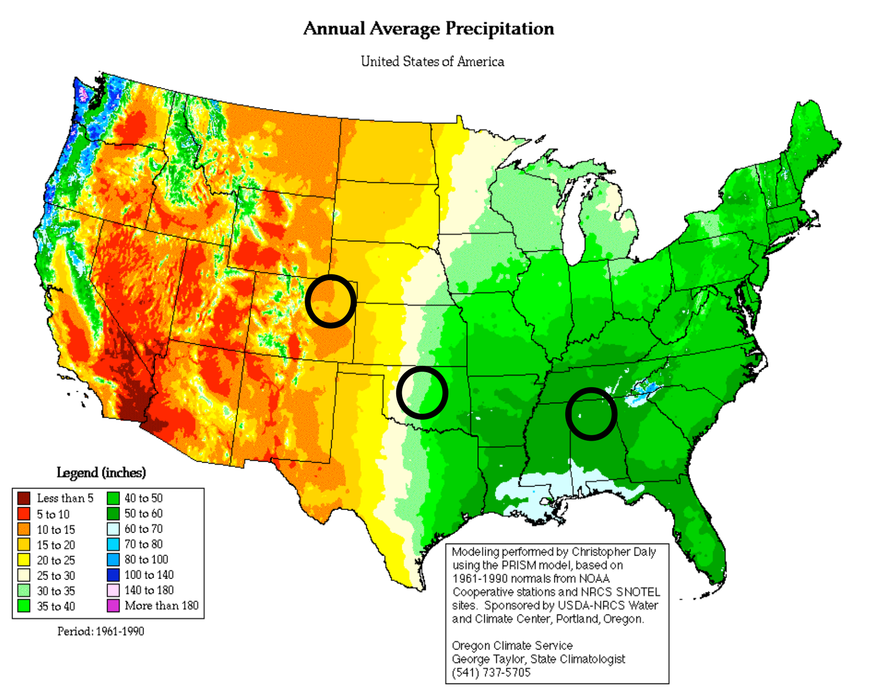
- DC3 would provide
  - NSF/NCAR G-V to sample the convective outflow and mass fluxes in the mid to upper troposphere, and convective plumes 100-1000s km downwind of the sampled, active convection
  - either the NASA DC-8 or the NSF/NCAR C-130 to sample the inflow of aerosol and trace gases and the mass fluxes in the middle troposphere
- ASP would provide the G-1 to sample the inflow of aerosol and trace gases and the mass fluxes in the lower troposphere

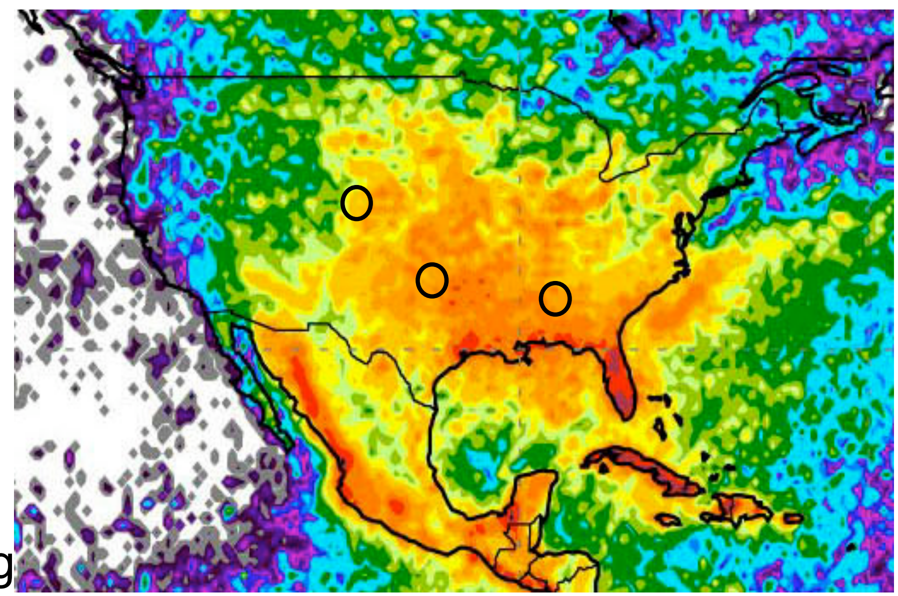
Setting

May and June 2011
7-8 week period

Northeast Colorado and Central Oklahoma and Northern Alabama

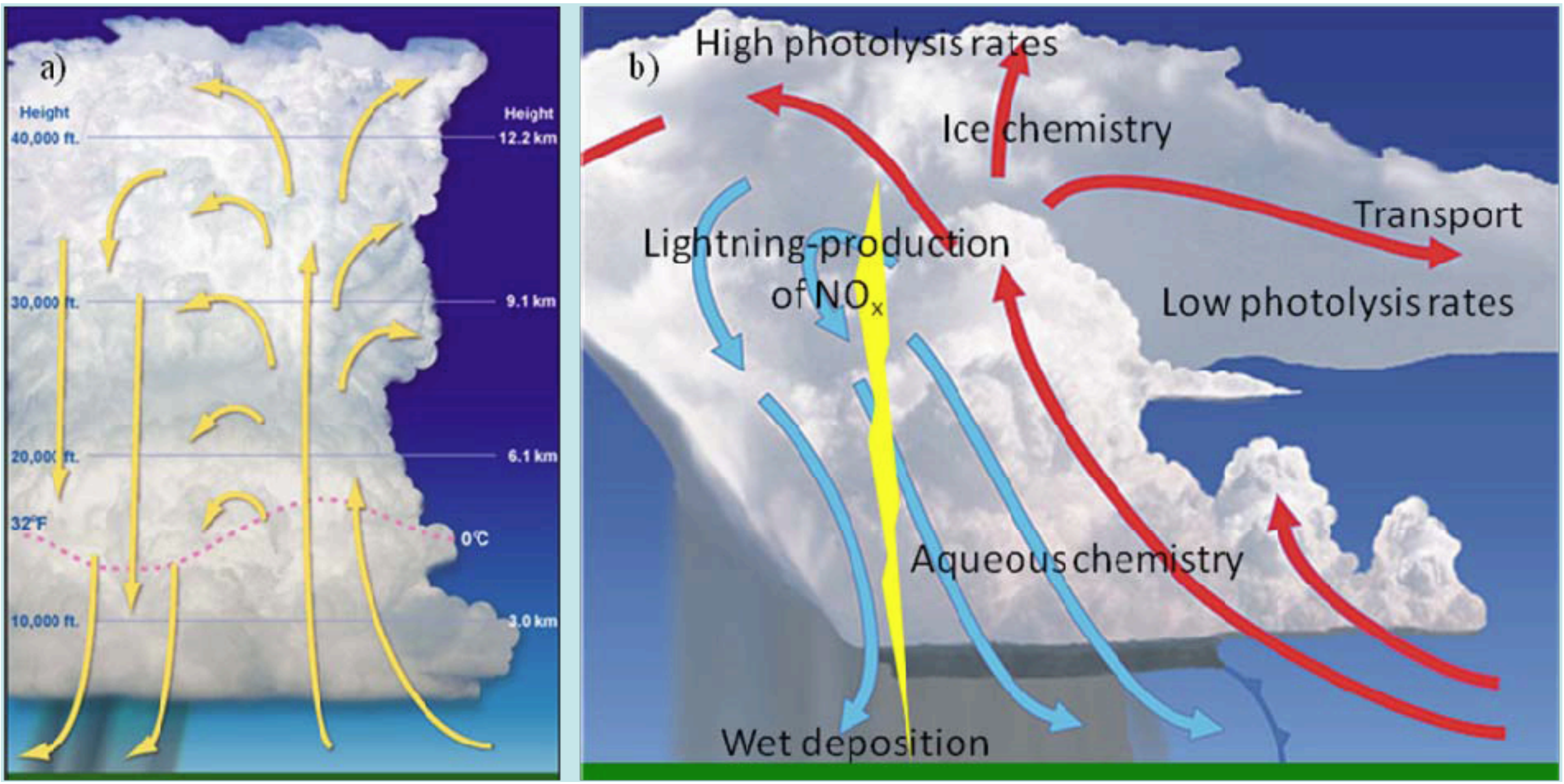
- Sufficient ground-based facilities
- Likelihood of convection occurring in one of the three places is good
- Contrast different environments (long-lived, shear storms vs airmass storms; high cloud bases vs low cloud bases; low chemical emissions vs higher emissions)





JJA Lightning

Questions?



a)
Height
40,000 ft.
30,000 ft.
20,000 ft.
32°F
10,000 ft.
Height
12.2 km
9.1 km
6.1 km
0°C
3.0 km
b)
High photolysis rates
Ice chemistry
Transport
Lightning-production of NO_x
Low photolysis rates
Aqueous chemistry
Wet deposition

Key Measurements

Measurement	DC-8	G-V	G-1
O_3, CO, HNO_3, SO_2	1	1	1
NO, NO_y, NO_2	1	1	1
H_2O vapor	1	1	1
Peroxides	1	1	1
Size-resolved aerosol comp (AMS)	1	2	1
Aerosol size distribution	1	2	1
CNC (7 nm)	1	1	1
Ice particles	1	1	
CVI		2	
Time-Resolved Aerosol Collector			1
CCN	1	2	1
Inorganic particulate composition	2		1
Radioactive tracers	1		
Aircraft standard (winds, T, P, location)	1	1	1
Vertical velocity	1	1	1

1: essential. 2. desirable

DOE Platform: Gulfstream-1

- Nominal operating altitude: 1,000 ft AGL to 25,000 ft (7.5 km) MSL
- Nominal sampling speed: 195 knots (100 m s^{-1})
- Nominal rate of climb: 500-1000 ft min^{-1} (2.5-5 m sec^{-1})
- Endurance with maximum fuel: 6 hours
- Crew capacity: 2 pilots and 1 to 5 scientists and engineers
- Cabin payload at maximum gross weight, with full fuel: 2,500 lb (1,134 kg) including scientific crew and instruments
- Cabin dimensions: 21 ft (6.4 m) long; 7 ft (2.13 m) wide; 6 ft (1.83 m) high
- Cabin floor space: 165 ft2 (15.3 m2)
- Entrance door dimensions: 29 in. (74 cm) wide; 58 in. (147 cm) high
- Interior cabin passage way dimensions: 29 in. (74 cm) wide; 68 in. (173 cm) high
- Standard 19" equipment rack dimensions: 17 & 24 in. (43 & 61 cm) deep; 22 & 42.5 in. (56 & 108 cm) wide; 42 in. (107 cm) high
- Floor mounting track width: 12 in. (30.48 cm)
- Supplemental air conditioning: 3 heat-exchangers in cabin rated at ~6000 BTU each
- Electrical power: 300 A @ 28 VDC provides 4,000 V-A at 115 VAC 60 Hz and 4,000 V-A at 230 VAC 60 Hz

DOE Real-time Aerosol Measurement Capabilities

Measurement	**Instrument**	**Technique**	**Range**
Size distribution	Tandem Scanning Electrical Mobility System (TSEMS)	Electrical mobility & optical counting	5 - 800 nm @ 60s noise ~N1/2
Size distribution	PMS PCASP-100X/DMT-SPP-200	Optical light scattering	0.1-3 µm
Condensation particle concentration	TSI 3010	Supersaturation + optical detection	>7 nm 0-105 /cm3
Ultrafine particle concentration	TSI 3025A	supersaturation + optical detection	>3 nm 0-105 /cm3
Particle organic composition	Aerodyne Aerosol Mass Spectrometer	TOF sizing, thermal vaporization, electron impact ionization, quadrupole MS	20 nm - 2 µm 0.1 µg/m3 10<m/z<300 amu @ 1 s integration
Isokinetic aerosol inlet	Brechtel inlet	Double-diffuser, active inlet	90 - 110 m/s TAS, 0-2500 m altitude

DOE Real-time Gas Measurement Capabilities

Measurement	**Instrument**	**Technique**	**Range**
O_3	TEI 49	UV absorption	5-500 ppb
SO_2	TEI 43S	Pulsed fluorescence	0.3-200 ppb
CO	Vacuum UV TEI 48	UV fluorescence IR absorption/gas filter correlation	<5 ppb @1 s 20 ppb @10s
$NO/NO_2/NO_y$	3-channel $NO/NO_2/NO_y$	O_3 chemiluminescence (NO) Photolytic conversion (NO_2) Hot Mo conversion (NO_y)	NO ~10 ppt @ 10 s NO_2 ~50 ppt @10 s NO_y ~100 ppt @10 s
NO/NO_y	TEI 42C	O_3 chemiluminescence	0.2-200 ppb
H_2O_2	3-channel Peroxide System	Glass scrubber, selective derivitization, fluorimetry	~60 ppt @1 min

DOE Time-Integrated Measurement Capabilities

Measurement	**Instrument**	**Technique**	**Range**
PAN	GC/ECD	Gas chromatography electron capture detection	50 ppt-100 ppb
NO_2 & PAN	NO_2 & PAN	GC/Luminol chemiluminescence	15-30 ppt
Particle ionic composition	Particle-in-Liquid System (PILS)	Liquid ion chromatography	~0.1 µg/m3 @ ~3 min
Single particle chemical composition	Time-Resolved Aerosol Collector	Impaction + CCSEM/EDX	0.2 - 7 µm >2 atomic % 30-60 s sample

DOE Cloud Measurement Capabilities

Measurement	Instrument	Technique	Range
Particle & Droplet size distribution	DMT CAPS	Optical light scattering	5-50μm
Particle & droplet imaging	DMT CAPS	Optical imaging	25-1550μm
Liquid water content	DMT CAPS	Hot wire	0.01-3.0 g/m3
Liquid water content and droplet size	Gerber PVM-100A	Optical light scattering	0-10 g/m3 2-70 μm
Droplet size distribution	PMS FSSP-300	Optical light scattering	2-47 μm
Droplet size distribution	PMS OAP-2D	Optical light scattering	20-1240 μm

Other

Measurement	Instrument	Technique	Range
Lightning	WX500 Stormscope	Static discharge detection	
Area precipitation	Honeywell-Sperry	Color weather radar	
Gust-probe differential pressure, dynamic	Rosemont 1221F2	Capacitive capsule with electronic conditioning (temperature correction, etc.)	0 to +100mb; -55°C to +71°C

What DOE Wants from DC3

- G-1 can't reach the detrainment level of deep clouds
- DOE ASP needs measurements of concentrations and detrainment rate (integrated around anvil) of
  - Tracers
  - Gases
  - Aerosol
  - Cloud